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PHYSICS.—*Time measurements.*[1]

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INTRODUCTION

According to precedent it is time for an address by your Junior Past President and the subject chosen is: Time Measurements. I propose to discuss very briefly concepts of time, units of time and a few of the many standards of time; and more in detail that particular class of time measurements which constitutes one of the three component parts of a fundamental or absolute measurement of electrical resistance, which at this time is my job.

The subject is timely, since most everyone is concerned with time measurements or at any rate talks about time, in the day time, in the summer time and at other time. We hear of fast time, slow time, record breaking time, waltz time, swing time, standard time, daylight saving time, sun time, middle European time, spring time, vacation time, slack time, Christmas time, correct time, present time, past time, future time, geologic time, all sorts of time, any time and more or less all the time, here, there and most everywhere. We even hear of before time began and when time shall be no more. We time the plays of a hand of bridge, our start to work in the morning, our going to meals and most everything we do. In the home we time the boiling of eggs, the baking of a cake, the roasting of a piece of meat, etc., etc. We also time the start of the cooking of the various parts of a meal so that each part will be finished at a more or less definitely specified time in advance of the time it is to be served.

Incidentally, what is the time: judging from my watch it is approximately 8:30 and it is p.m. (not a.m.) January 15, 1938. But it is 7:30 p.m. in Chicago, 6:30 p.m. in Denver and 5:30 p.m. in San Francisco. Furthermore, it is 2:30 a.m. January 16, 1938, in Berlin. Yet time is the same everywhere—or is it possible that it is not. At any rate, it is approximately one hour and 30 minutes January 16, 1938, Greenwich Meridian time here and elsewhere on this earth. However, time does

[1] Address of the retiring president of the Philosophical Society of Washington, delivered January 15, 1938. Received October 31, 1938.

not have much if any meaning to us as something apart from the place in which we are. Time and place, or more specifically space, are of equal importance to us and are more or less inseparable. For example, some of us have found by sad experience that two people cannot occupy the same space at the same time.

Since apparently there are many kinds of time, and time and space are so intimately associated, it would be in order, before proceeding further, for each of us to ask herself or himself what is time and what is space. A little thought will lead to the conclusion that to most of us at any rate the words time and space denote fundamental concepts or general ideas which cannot be defined. Our concept of time and of space differs more or less depending on our individual experiences, but presumably all will agree that time and space serve to specify the when or duration and where or size of any event. You are not likely to attend a party to which you may have been invited unless you know both when and where the party is to occur.

Considering only the experiences of most of us, time and space may be thought of as separate entities to about the same extent as the space coordinates usually designated x, y and z may be thought of as independent. Letting t represent time, the coordinates applying to any particular event may be taken as t, x, y and z. Only by a process of mental abstraction can one of the space coordinates be separated from the other two or the time coordinate be separated from the space coordinates.

To see that this is so, consider how a measurement of length or of time could possibly be made without at least a limited amount of three dimensional space in which to make the measurement. To coordinate a few of the observations of a relatively few broader concepts of time and space are required. As a consequence we hear of relativity theories and space of more than three dimensions. However, in this discussion of time measurements consideration will be given only to problems in which relative velocities are small in comparison with the velocity of light, that is to problems not requiring these broader concepts of time and space.

In order to specify an event it is necessary to select an origin for each of these 4 coordinates and a unit for each. For the 3 space coordinates usually 3 mutually perpendicular planes, with the point of their intersection taken at will, serve as the origins of the space coordinates and the same unit is used for each. For the time coordinate the origin may be taken at will, while usually the mean solar second is used as the unit. Other units of time used are the sidereal second, the

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minute, hour, day, week, the mean solar day, month, etc. In the measurement of time as in the measurement of other quantities we must have not only a unit and frequently an origin but also a standard or measuring instrument.

The unit, origin, and standard used in any particular case depend to a greater or less extent on the nature and purpose of the time measurement. With reference to events of interest throughout the world usually the Gregory calendar with its fixed origin serves in determining the year, the month and the day of the month, while the mean solar second and multiples of it such as the minute and hour together with a standard time zone is used in specifying the time. For example, a particular train may have left the Union Station, Washington, D. C., on December 14, 1937, at 4 h, 29 min, 37 seconds p.m. Eastern Standard Time. The observation of when the train left the station constituted a time measurement in the sense of accurately determining a date. In many cases a time origin is of minor importance. For example we hear such expressions as "Meet me at 12th and G Streets in half an hour." Obviously, therefore, clocks and watches are used in measuring time intervals or the difference between two dates which are nearly the same and may or may not be known.

If the time interval to be measured is very short an ordinary watch or clock cannot be used in the measurement except possibly indirectly.

In still other cases the measurement consists in determining the time interval between a more or less continuously reoccurring event. For example, a machine has a rotating part and the time measurements consist in determining the average over a few or many revolutions of the time interval of one revolution. If the time interval is short usually the result obtained is expressed not as the duration of one event but as the number of repetitions of the event in a unit of time, while the measurement is called a frequency determination. Precise frequency determinations generally are the most difficult and most intriguing class of time measurements, since in many cases they involve the maintenance of the frequency to be determined.

Time measurements in general, therefore, may be divided into 5 or more classes, such as extremely long time intervals, dates, moderately short time intervals, extremely short time intervals, and frequencies.

THE PRIMARY STANDARD AND UNIT OF TIME

Having mentioned some of the classes of time measurements it is in order to consider briefly some of the standards used. As has already

been pointed out, for at least most time measurements some sort of standard of time is necessary while a standard suitable for one class of measurement may not be suitable for some other class. Consequently different types of standards are used. That the result obtained with one type of standard shall be the same as though some other were used the different types must be compared among themselves and if more than one standard of a particular type is used these must be compared either directly or indirectly with each other. From among the vast number of standards it has been found convenient to select one for use as a primary standard, that is as a standard with which to compare all other time standards or time measuring devices. The one selected is the revolution of the earth on its axis. The duration of one revolution of the earth on its axis constitutes a sidereal day, which might be used as a unit of time, but the use of this unit would be decidedly inconvenient. Other standards which might be used as a primary standard are the revolution of the earth's moon in its orbit, the eclipsing of one of the moons of Jupiter, the eclipsing of a bright and dark star doublet, or one of the periods of the light radiation from some particular chemical element.

Some of these apparently would serve as a more reliable primary standard than the one being used.

From long continued astronomical observations the relation between the sidereal day and the mean solar day and consequently the mean solar second (the commonly used unit of time) has been accurately determined. While the primary standard is available to all, only those having very special equipment could use it directly in any precise measurement they might desire to make. In most time measurements some type of clock or watch is used either directly or indirectly as a standard. Clocks and watches are set and regulated by comparisons with the primary standard, but for the most part these comparisons are decidedly indirect. In various countries some one or more laboratories make observations of the primary standard and broadcast the data obtained in such form that they may be used readily in setting, adjusting rates and determining rates of clocks and watches. In this country our Naval Observatory furnishes this service.

PRECISION CLOCKS

All here are familiar with the pendulum clock, in general use in Washington until comparatively recently and still in general use in most rural districts, with watches and with the balance wheel type

of clock. In passing it should be pointed out that the so-called electric clocks now in general use in Washington and most cities are not clocks but synchronous motors suitably geared to hands moving over clock dials. Time will not permit of descriptions of any of the great variety of clocks, chronometers and other time measuring devices which are one or two orders better than household clocks or serve some special purpose. Therefore, our consideration of clocks will be limited to those of precision types. In design, materials and workmanship these are as much superior to ordinary household clocks as the automobiles of today are superior to the ox-carts of a hundred years ago. Only a few of these clocks can or need be described and in the descriptions an effort will be made to point out essential features rather than details. In other words, the descriptions will be from the standpoint of the physicist rather than from the standpoint of the master craftsman.

Usually it has been assumed (at any rate until very recently) that a pendulum swinging without interference or with the least practicable interference by the driving mechanism constituted the best means of realizing really high quality clocks. Consequently a great deal has been said about free pendulums, while a free pendulum is so definitely an ideal towards which designers strive that they are reluctant in admitting that their clocks do not have completely free pendulums.

This matter was discussed more than 15 years ago by one of your past presidents, but I am sure that those of you who were here then and remember what he said will pardon me if I follow to some extent his procedure in analyzing the effect of the driving mechanism of an oscillating system upon its rate. Assume that a pendulum swinging without restraint, other than air damping, receives a sudden driving impulse somewhat past the center of each third swing to the right. For these conditions the energy changes are shown to a first approximation by figure 1. Here the approximate spiral is made up of semicircles drawn about the points a and b. The square of the radius vector R is proportional to the energy stored in the system, that is to the square of the displacement plus the square of the velocity. During the impulse the radius vector changes from o-m to o-n, that is, is increased in length and is set backward in its rotation. It is set backward because the velocity is increased without an appropriate increase of the displacement. It will be seen that except during impulses the radius vector decreases more during the time the velocity is towards the center of oscillation than it does during the time the velocity is away from the center of oscillation, showing that air damping slows the rate or increases the period. Energy diagrams of this general type serve

to show, at a glance, qualitatively and to a considerable extent quantitatively how the rate is affected by the abstraction of energy from or the addition of energy to the oscillating system in any part or parts of a cycle. It will be seen that driving impulses when the system is at the center of its swing do not affect the rate. Consequently many de-

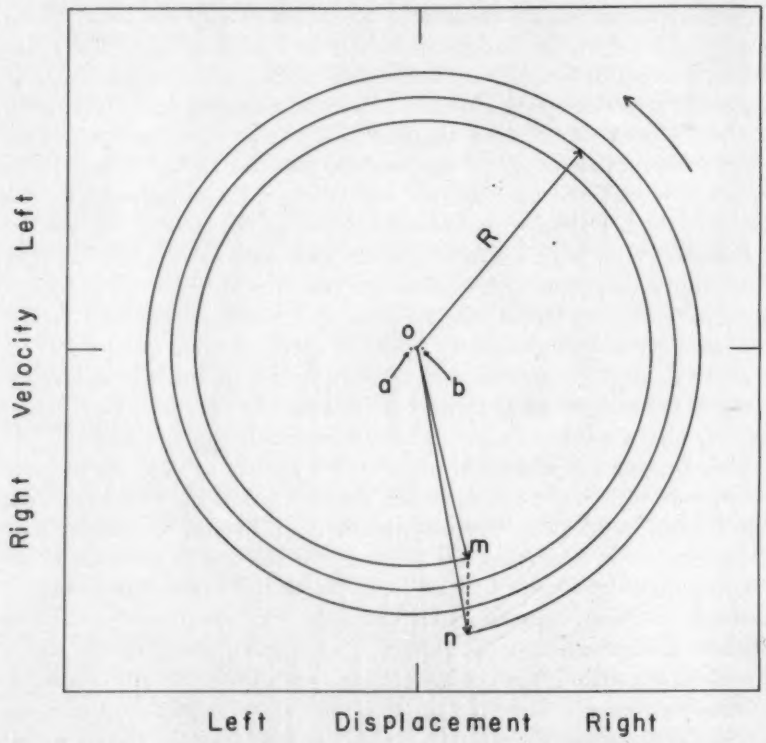


Fig. 1.—Energy diagram of damped oscillating system. Oscillation sustained by sharp driving impulse slightly past the center of each third swing.

signers strive for very short driving impulses at instants when the system is at its center of swing. However, it is readily seen that impulses whether positive or negative do not affect the rate if distributed symmetrically about the center of oscillation.

Strictly speaking, a free pendulum is one whose rate is not affected by the energy taken from nor the energy added to it. However, it is generally considered that a pendulum is free if the only energy taken

from it is that absorbed by air damping and this energy is supplied by a driving mechanism which does not affect the rate.

Thirty years ago the Riefler clock was generally considered to be the best of the precision clocks. As it is still being used to a considerable extent and is described as having a completely free pendulum, let us consider the basis for this claim and at the same time note how the motion of the pendulum is maintained.

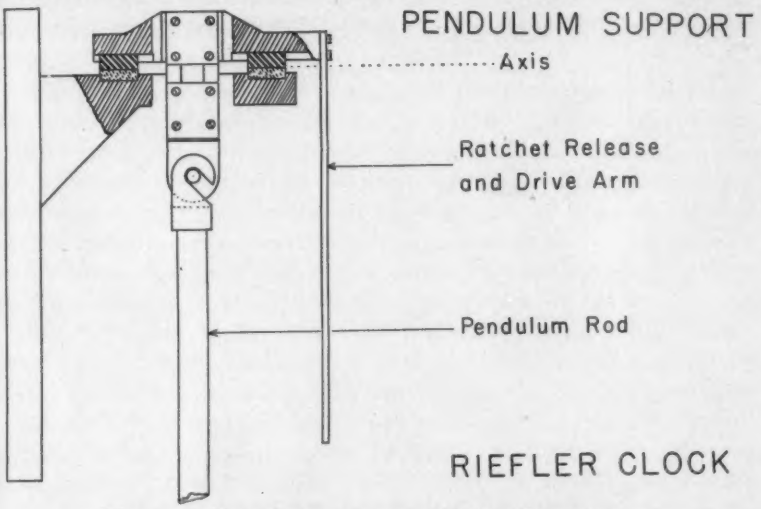


Fig. 2.—Riefler pendulum support and driving mechanism.

Figure 2 shows the pendulum support, driving spring, and ratchet release and driving arm. The ratchet release and driving arm contacts two toothed wheels mounted on the drive shaft. One of these toothed wheels and jewelled pawls on the ratched release and driving arm serves to intercept the forward motion of the drive shaft. Following releases of the ratchet, slightly after the pendulum passes the center of its swing, the other toothed wheel and pins on the ratchet release and driving arm move the driving arm in a direction opposite to that in which it moved in releasing the ratchet, bringing the driving arm against a definite stop. The result is that following each release of the ratchet the driving spring is suddenly stressed in the direction tending to move the pendulum towards the center of its swing, while the motion of the pendulum is away from its center of swing. The ratchet wheel teeth and jewelled pawls are so shaped that friction of the ratchet is largely compensated.

Figure 3 shows the manner in which the force exerted by the driving spring is distributed throughout a cycle, assuming that the friction of the ratchet release is perfectly compensated. Here the enclosed area is proportional to the energy transmitted to the pendulum by the driving spring during a complete period. It will be seen that driving impulses are neither concentrated near nor symmetrically distributed about the center of swing. Also it will be seen that the motion of the pendulum is continuously influenced by the driving mechanism, that is the pendulum is not free during any part of a cycle nor during

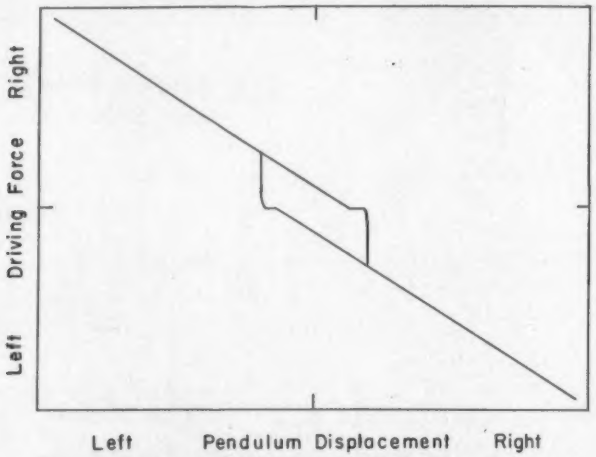


Fig. 3.—Action of Riefler ratchet release and drive spring.

any part of the time. Furthermore, friction of the ratchet release can not be perfectly compensated since static friction exceeds moving friction and the viscosity of the lubricant changes with time. Consequently the effect of the driving mechanism upon the rate cannot be presumed to remain constant.

In the Riefler clock time signals are given by an electrical contact operated by a third toothed wheel mounted on the drive shaft. Since the ratchet release is not positive in its action and the teeth on neither of the two wheels involved can be alike, time intervals between successive contacts are not constant. In case of the Riefler with which I have had much sad experience these time intervals vary by as much as 0.02 second.

A clock of more recent design is the Shortt Synchronome. This clock consists of two distinct parts each having a pendulum. These

parts, designated "Free" and "Slave," may be located at a considerable distance from each other since connection between them is by means of electrical circuits. The slave, which runs slightly slow, operates the contact in the circuit supplying the power driving the free pendulum. It also operates clock dials and time pick-up contacts. The free pendulum keeps time and each 30 seconds closes a contact in a circuit which in case the slave is slightly behind, steps it forward a few thousandths second. The free pendulum receives a driving impulse each 30 seconds. Otherwise its motion is free except for air friction and unavoidable movements of its support.

Figure 4 shows the manner in which the driving impulses are transmitted to the pendulum as well as the manner in which the contact synchronizing the slave is operated. It should be pointed out that a driving impulse is applied to the pendulum only when it is near the center of a swing. Furthermore, the driving impulses begin slightly before the pendulum reaches the center of its swing and continue until the pendulum is slightly past its center of swing. Aside from air damping the pendulum is strictly free about 99 per cent of the time.

Time signals are given by a contact operated by the slave. Consequently they are affected by the method of synchronization of the slave with the free pendulum. The contact made by the free pendulum is undoubtedly more reliable but not sufficiently frequent for many purposes. Time will not permit of descriptions of the various devices which have in individual cases been added to Riefler and Shortt clocks to give more satisfactory time pick-ups. Both of these clocks usually are operated in a partial vacuum for the purpose of reducing the power required to drive them since a reduction of the power reduces the effect of the drive on the rate, that is makes the pendulum more nearly free. However, it also makes the arc of the pendulum swing more subject to variation and variations of arc result in variations of the rate. One of the most important developments in pendulum clocks since the advent of the Shortt is the maintenance of a constant or practically constant amplitude. Various means have been devised for accomplishing this.

Obviously, the drive affects the rate not only of pendulum clocks but also of watches, chronometers and all other types of clocks involving an oscillating system, whether mechanical or electrical, or partially mechanical and partially electrical. It is now in order to state an ideal towards which designers of clock drives might well strive: namely, drives having a constant direct effect on the rate and maintaining a constant amplitude best suited to each individual case. Whether or

not the effect of the drive on the rate is zero is immaterial. However, in most cases the more nearly it is zero the more easily it may be made constant.

The Riefler and Shortt clocks were designed primarily for use in astronomical observations. They are not very suitable for the measurement of relatively short intervals of time: First, because their rates are continuously changing on account of microseisms which are more or less harmonic movements of the ground having periods usually in

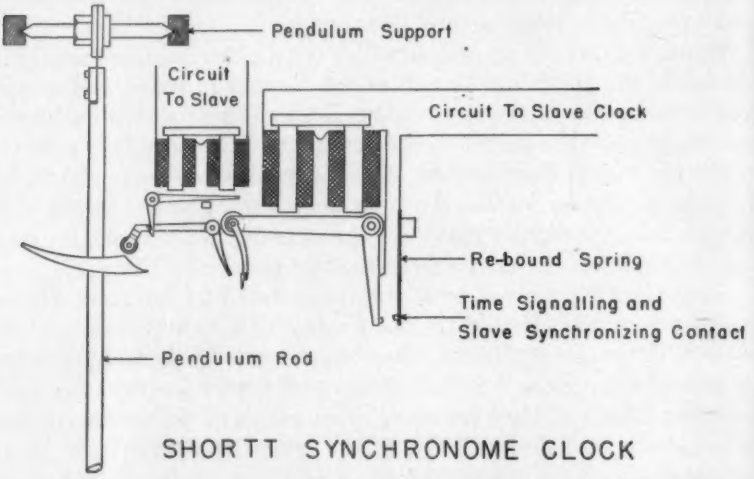


Fig. 4.—Shortt synchronome free pendulum support and driving mechanism.

the range from 3 to 8 seconds and amplitudes of a few microns. Microseisms keep the pendulum support in an extra motion which changes the rate alternately in one direction and then in the other. Second, because it is not possible to pick up time from these clocks neither precisely enough nor frequently enough for use directly in certain classes of physical measurements. For some of these measurements what is needed is a precision clock which, to use a homely expression, "ticks" a relatively large number of times per second, while it is desirable that the number of ticks per second be adjustable in definite step up to a maximum of not less than 100,000,000. To date this feature has been realized only in the crystal clock with its auxiliary equipment.

All the better types of clocks have a mechanically oscillating system, such as a pendulum acted upon by gravity, a balance wheel acted upon by a spring, or other device having mass which may be dis-

placed or distorted and an elastic restoring force proportional to the displacement or distortion. In the crystal clock this mechanically oscillating system is a quartz crystal cut to dimensions such as to give a desired period or frequency. Quartz in addition to having excellent elastic properties is piezo-electric. That is, changes its dimensions when placed in an electric field and produces an electric field when its dimensions are changed.

(A large quartz crystal shown and optic and electric axes pointed out. The manner in which the crystal would be cut relative to these axes in making a piezo-electric oscillator explained. An unmounted oscillator having a frequency of approximately 200,000 cycles per second shown. Also an oscillator mounted between plates used to apply the electric field necessary to maintain the mechanical oscillation and from which this oscillation is picked up electrically without mechanical contacts shown.)

In what follows I shall assume that you are familiar with the simpler radio tubes, the simpler radio circuits and the symbols used to

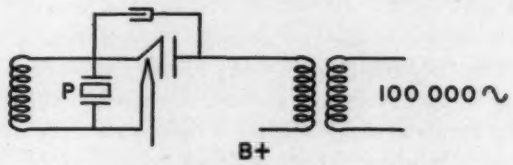


Fig. 5.—Piezo-electric oscillator drive and pick-up circuit.

represent the various parts of such circuits. Figure 5 shows one of the simpler electric circuits serving to maintain a quartz crystal in oscillation and at the same time supply an alternating current of the same frequency as the mechanical oscillation of the crystal. Here P represents a quartz crystal assumed to be so cut as to have a natural frequency of 100,000 cycles per second. Otherwise the arrangement is a simple oscillating circuit with a capacitance feed back and transformer output. Figure 6 shows a circuit of a frequency multiplier. Here it is assumed that the input to the first tube is 100,000 cycles per second and of such amplitude as to greatly overload the tube. Consequently the output of this tube is rich in harmonics either odd or even or both odd and even. The input to the other tube is tuned to one of these harmonics in the same way that an ordinary radio receiving set is tuned to a particular broadcasting station. Consequently if the second tube is operated without appreciable distortion most of its output will have a frequency of N 100,000 cycles per second where N is an integer in the range from 1 to 15.

Figure 7 shows a circuit of a frequency divider. The arrangement is such that each of the two tubes feeds through a capacitor to the grid of the other. The capacitances and resistances are so chosen that the system tends to oscillate when there is no input with a frequency of

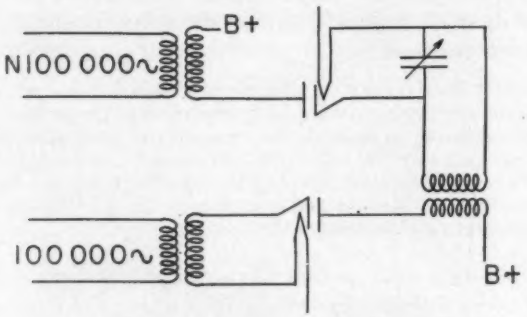


Fig. 6.—Frequency multiplier circuit.

approximately 50,000 cycles per second. Then in case of an input of exactly 100,000, 150,000, 200,000 etc., cycles per second it will oscillate at exactly 50,000 cycles per second. A circuit of this type may be definitely synchronized at a frequency which is a simple fraction of the input frequency. While divisions of 10 or more may be made in this

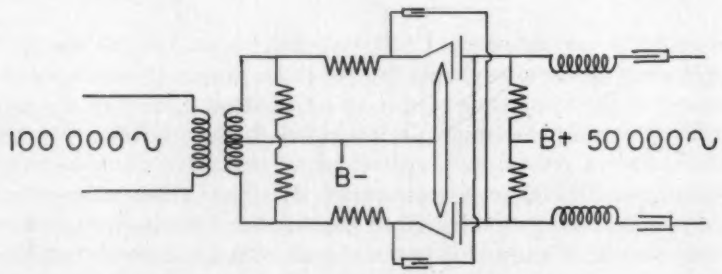


Fig. 7.—Frequency divider circuit.

way adjustments are more easily made and maintained if the division does not exceed 5.

Frequency multipliers and frequency dividers may be used in tandem and in combinations with each other so as to give a great range of frequencies, all having a fairly simple and definitely known relation to the initial frequency.

A crystal clock with frequency multipliers and frequency dividers

constitutes a precision time measuring equipment giving simultaneously different frequencies or numbers of ticks per second ranging from 1000 or less to 100,000,000 or more. If in addition a synchronous motor is driven from one of the lower frequencies and this motor drives a clock train which operates electrical contacts the range may be extended downward an additional 5 or more orders. It is also possible to extend the lower end of the range somewhat without the use of a synchronous motor or other moving mechanical parts.

Which of the various number of ticks per second that are available or might be made available may be observed or counted depends upon the purpose for which they may be used. In cases in which electrical contacts are operated by a synchronous motor observation and use may be similar to that which is used with clocks of the pendulum type or chronometers. However, in most cases the number of ticks used lies somewhere within the range from 1000 to 100,000,000 per second. How a large number of ticks per second (5,000,000 for example) might be observed and used need not be discussed here since the National Bureau of Standards issues in mimeographed form instructions for their observation and use for a particular purpose. Later I shall try to explain somewhat in detail how 1000 ticks per second may be used so as to give, in effect, time pick-ups every 0.011 second to a precision of approximately 0.00001 second.

TIME SERVICES

The Naval Observatory broadcasts time signals during the last 5 minutes of most every hour of the day. In some cases these broadcasts are on two or more carrier frequencies, all outside the regular broadcast band and all without an audio frequency modulation. These signals consist of second pulses with certain omissions which serve to identify both the minute and second of each pulse. They serve in giving the time of day usually to a few hundredth second and are used directly in setting, adjusting rates, determining rates and determining corrections to the better grades of watches, clocks and chronometers and indirectly in the setting of most, if not all, household clocks and watches.

Regular broadcast stations usually announce the time every 15 minutes. This is undoubtedly the most generally used time service.

To a limited extent portions of broadcast programs are recorded photographically at a number of places along with time signals from a local clock. These records when brought together serve as a means of determining the correction to the signals from each clock relative

to the time signals given by one of the clocks used as a reference standard.

Power service stations for the most part maintain the frequency very close to 60 cycles per second. Further, they operate cycle counters or synchronous motors driving a clock train and from time to time speed up or slow down their generators so that the average of the frequency between interruptions of the service is almost exactly 60 cycles. This is what may be called an extra service purely for the convenience of those using so-called electric clocks.

The National Bureau of Standards broadcasts on Tuesdays and Fridays

from 10:00 to 11:30

a carrier frequency of 5 mc/s

from noon to 1:30

a carrier frequency of 10 mc/s

from 2:00 to 3:30

a carrier frequency of 20 mc/s

each without modulation, except a short pulse each second and announcements at the beginning and end of each 90-minute period.

On Wednesdays at the same hours and on the same carrier frequencies a 1000 c/s 30% modulation except during announcements.

Evenings except Saturday and Sunday from 4 p.m. to 2 a.m. and except during rather frequent announcements full modulation at a frequency of 440 c/s on a carrier frequency of 5 mc/s.

In general the frequencies broadcast, whether carrier or modulation, differ from their nominal values by not more than 1 part in 10,000,000. The second signals on the average have the same accuracy as the carrier frequencies. However, it should be pointed out that all time signals transmitted by radio are affected by the time of travel from the sending station to the receiving station, which varies to some extent because of what is popularly known as fading.

The 5, 10 and 20 mc/s serve broadcast stations and others concerned with radio transmissions, in adjusting their carrier frequencies. The 1000 c/s serves in testing audio equipment and in scientific investigations. The 440 c/s serves musicians since this is the international standard A above middle C pitch. Neither the second signals nor the modulations interfere in any way with the use of the carrier frequencies for their primary purpose.

These various time services, that is of the Naval Observatory, etc., in no way involve a duplication of effort. Each represents an effort to

meet a distinctly different need and each is supplemental to the others.

REGULATION AND MEASUREMENT OF SPEED OF ROTATION

Near the beginning of this talk the statement was made that precise frequency determinations usually are the most difficult and most intriguing type of time measurement since in many cases they involve the maintenance of the frequency to be determined.

Those of you who are familiar with measurements in general know that the accuracy attainable in any measurement may be limited by a lack of constancy or definiteness of the quantity being measured. As an illustration consider the distance from the trunk of a tree to the tip of a branch which is being swayed by the wind. While the position of the tip at some particular instant might be noted and the distance from this position to the trunk measured, the result obtained very probably would differ considerably from the result which would be obtained by again noting the position of the tip of the branch and measuring the distance from this second position to the trunk of the tree. Obviously if the distance from the trunk to the tip of the branch is to be more or less dissociated from time some means must be provided for preventing the swaying.

If a measurement of the frequency of a rotating machine, that the number of revolutions per second over a more or less indefinite time instead of the number of revolutions in a particular second, one sixtieth of the number of revolutions in a particular minute or other time having an arbitrarily selected origin, is to be made to a specified accuracy, means must be provided for keeping the frequencies constant, at least within limits corresponding to the specified accuracy.

In the investigation referred to above and on which most of the members of my section in the National Bureau of Standards are devoting their major effort, it is necessary to determine the average speed of a rotation shaft as weighed in a particular way over successive 15-second intervals of time to one or two parts in 1,000,000, with a variable friction load amounting to about 1/3 horsepower. While this is a rather vague statement of the problem, a definite statement would require a discussion of the characteristics of some of the instruments used and the analysis of experimental data pertaining to parts of the investigation not being considered at this time. The solution obtained may be understood more readily by considering an analogy. Since the weighted average peripheral speed of one of the wheels mounted on the shaft is 44 miles per hour, it will be assumed that an automobile

is kept at the rate of 44 miles per hour by the following procedure. Along the course to be followed by the automobile the distances to be covered in each 0.011 second are marked off. Also the distances to be covered in each 0.001 second are marked off. The former marks are for use in controlling and measuring the speed. The latter are for casual visual observations, just to see that the control is functioning properly. The operation is in semi-darkness and the clock used in the measurement flashes a lamp each thousandth second, illuminating the marks showing the distances to be covered each 0.001 second. If the control of the speed were perfect and the action of the clock were perfect persistence of vision would make these marks appear stationary. The arrangement constitutes what is generally known as a stroboscope.

The lines spaced at the distances to be covered each 0.011 second consist of electrically insulating paint on an otherwise electrically conducting road bed. Two brushes, placed adjacent each other and carried forward by the automobile, contact the road bed. These brushes are connected by wires to a mechanism which shifts the engine throttle between stops. When the throttle is set against one of the stops the power developed by the engine is not sufficient, while when it is set against the other stop it is in excess of that required to maintain the specified speed. Furthermore, each 0.001 second the clock used in measuring the speed applied an electromotive force to the circuit for approximately 0.0002 second. In case the brushes touch one of these insulating lines during the 0.0002 second time intervals it is an indication that the automobile is ahead of its schedule. This condition manifests itself by the appearance of an electrical potential difference between the brushes. The equipment is made sufficiently sensitive that should this potential difference continue for only 0.0001 second or even less it will cause the throttle to shift to the position at which the power developed by the engine is not sufficient to maintain the specified speed, or specified time distance schedule. A hundredth second later the throttle is automatically set to the other position, that is to the position at which an excess power is developed by the engine and after an additional thousandth second the cycle begins repeating itself, provided the automobile is still ahead of its schedule. However, if it is behind its schedule there is no electromotive force in the circuit during the time the brushes are insulated. Consequently the throttle is left in the position at which an excess power is developed. The throttle remains in this position until the automobile is again ahead of its schedule and the brushes are insulated during

a part of the following time signal from the clock, when the throttle is shifted against the other stop. It will be noted that the power developed by the engine is always more or less than that which would maintain the time-distance schedule. There is no provision for supplying at each instant the amount of power which might be required in maintaining the schedule. Yet at no time is the automobile ahead or behind its schedule by as much as 0.0001 second or 0.1 inch from the place at which, according to the schedule, it should be. Furthermore, the automobile is alternately ahead and behind schedule four to six times each second, by approximately equal amounts.

From the brief description given above of the method of control there has been omitted an important element, namely time lags. It would not be possible to change the setting of the throttle from one stop to the other instantaneously. In addition, the time pick up from the clock is not continuous but only once each 0.011 second. Consequently there is a possibility of a time lag of from 0 to 0.011 second from this source. Time lags from other sources may amount to as much as 0.002 second.

A little consideration will show that without a stabilizing device time lags would cause the automobile to run alternately ahead and behind its schedule by ever increasing amounts until out of control.

(Illustrated by both hand operated and fully automatic demonstration apparatus.)

No precision clock has ever been made from which time can be picked up continuously while with moving mechanical parts it is not practicable to use an exceedingly large number of ticks per second, so it is not possible to eliminate the cause of the oscillation. However, if the time lags are not excessive, the amplitude and period of the oscillation may be stabilized but cannot be suppressed entirely.

To obviate this difficulty when the throttle is against the stop for which the power is excessive both stops are moved somewhat gradually in the direction reducing the power. Likewise, when the throttle is against the stop for which the power is deficient both stops are moved somewhat gradually in the direction increasing the power.

(That this results in stabilization illustrated by fully automatic demonstration apparatus.)

The problem under consideration is an almost exact duplicate of the imaginary one just considered except that only a relatively small space is required instead of miles and miles of clear roadway; the power is supplied by an electric motor or rather two electric motors

instead of an automobile engine; the power is controlled by a grid tripping mercury vapor tube instead of a throttle; and stabilization is accomplished by an inductor instead of mechanical displacements.

To facilitate quick responses to changes in the load and in the potential difference of the power supply the number of mechanical parts operating independently of each other are reduced as far as possible. Excepting vibrations resulting from defects in the balance and other mechanical imperfections, the only mechanical movements in the entire system are the vibration of the quartz crystal of the clock and the rotation of parts rigidly connected to the shaft or in effect so connected.

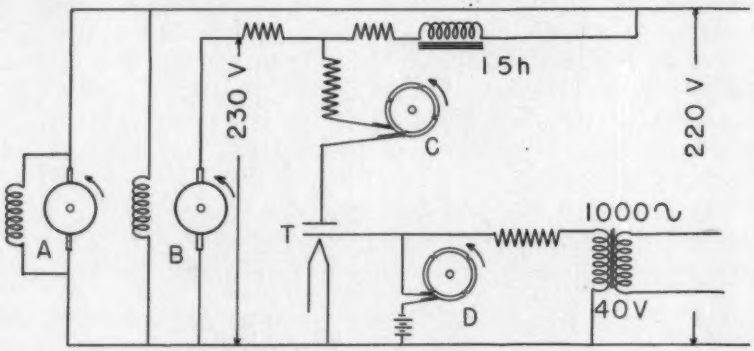


Fig. 8.—Drive circuit of direct current motor synchronized with alternating electromotive force.

The circuit arrangement, excepting the clock supplying the 1000 cycle per second control electromotive force and the stroboscope, is shown in figure 8. An important element of this circuit is the grid tripping mercury vapor tube designated T.

(A tube of this type shown and its action explained.)

A represents a motor supplying power in excess of the mechanical load. B represents a motor over excited so that it functions as a generator thus absorbing power from the rotating shaft. The amount of power absorbed from the shaft depends upon the current in the armature of the motor, B, and this in turn depends on whether the mercury vapor tube is in the conducting (ionized) or non-conducting (deionized) state and the current in the 1.5 henry inductor. The commutator C serves to break the circuit through the mercury vapor tube each 0.011 second for approximately 0.001 second, the time required for

the tube to deionize. The commutator D in conjunction with the 1000 cycle per second control electromotive force serve to trip (that is ionize) the mercury vapor tube when the motor is ahead of its schedule.

The manner in which the potential on the grid of the mercury vapor tube varies during a small fraction of a revolution of the motor when it is a few hundred-thousandths of a second ahead of its schedule is shown in figure 9.

The manner in which the power supplied by the motor A exceeds the power absorbed by the motor B under normal operating conditions is shown in figure 10.

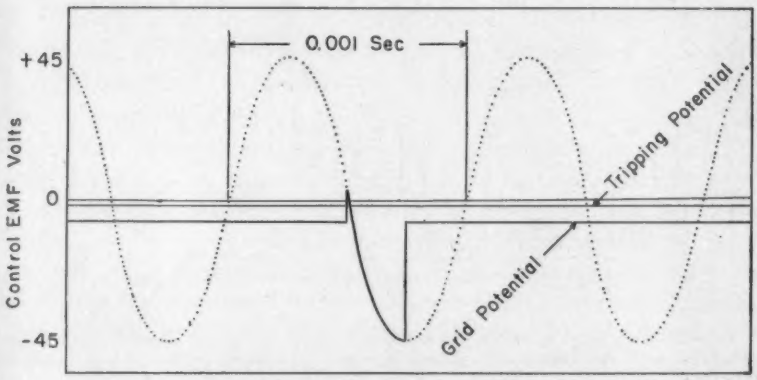


Fig. 9.—Action of time-up with motor slightly ahead of its schedule.

The apparatus was so designed that with a constant time lag of 0.01 second its operation would be stable and oscillate above and below the synchronous speed about 5 times per second. The period of oscillation is determined by time lags and electrical constants of the circuit. The amplitude of the oscillation is determined by the difference between the two amounts of power developed by the motors and the moment of inertia of the rotating system. The moment of inertia might be made so large that the amplitude of the oscillation would be exceedingly small. However, if the amplitude were exceedingly small to obtain positive operation it would be necessary that the time pick up from the clock be much more precise than 0.00001 second. Time pick ups to a precision of 0.000001 or even 0.00000001 second present no difficulties provided no mechanical movements are involved in the process. However, when they involve the use of mechanically operated contacts, 0.00001 second seems to be nearly the limit attainable.

It should be pointed that the comparison of the average angular speed of rotation of the shaft with the rate of vibration of the piezo-electric oscillator or crystal clock is made by a visual observation of the stroboscope to see that the equipment is functioning properly.

The performance of the clock is checked more or less continuously by those maintaining a group piezo-electric oscillators and determining their rates by comparisons with time signals from the Naval Observatory. Assuming no systematic errors in these time signals, the

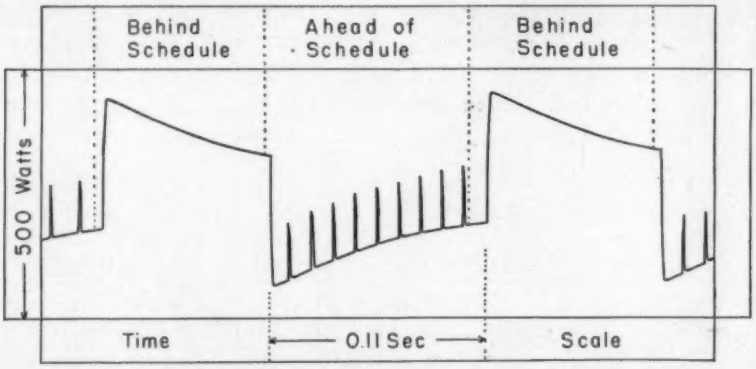


Fig. 10.—Variation of electric power supplied to direct current motor synchronized with 1000 cycle per second alternating electromotive force, under normal operating condition.

rate of the crystal clock used is known at all times to better than 1 part in 10,000,000, or about 1 second per year.

The equipment was not designed to give the highest attainable constancy of angular speed with a considerable variation in the mechanical load, but only a sufficient constancy to meet the requirements of the investigation in which it is being used. Some of you have seen the apparatus in operation and all of you are hereby invited to do so. It is expected that the apparatus will be kept in readiness for use or demonstration at almost any time during the next few years so you can see it more or less at your convenience.

In this talk on time measurements it has been possible merely to touch upon a few of what may be called high spots. No phase of the subject has been covered in detail. Furthermore, no reference has been made to measurement of the time two elastic bodies are in contact in case of collision, the design of extremely fast acting relays, and measurement of the time of their action, nor to the design of a machine

gun control and measurement of the time of action of the component parts. These are mentioned now merely because it is customary for each of your presidents on retiring to give a fairly comprehensive report on his work (or what one has more aptly called explorations) in some particular field. Possibly at some future time I may be permitted to tell you something of the other component parts of the investigation mentioned at the beginning of this talk. While I have been a member of this society for slightly more than 30 years and am now (to some extent at least) being relieved of responsibility in connection with its management, I trust that you will not look upon me as a retired member.

BOTANY.—*New South American species of* Dryopteris, *section* Glaphyropteris.[1] C. V. MORTON, U. S. National Museum.

Glaphyropteris is entirely an American section of *Dryopteris*, distinguished from section *Lastrea* by the presence of aerophores at the base of the costae, and usually also of the costules. Six species are recognized by Christensen in his monograph of *Dryopteris*.[2] Recent South American collections have revealed four additional species. In order to relate these satisfactorily to those previously known, a key to all has been prepared. A few notes on the older species are given also, but the present treatment is not to be regarded as a critical revision of the section. The types of most of the species are not available for study, and the writer has accepted Christensen's identifications and delimitations, except for one variety here raised to specific rank. Since the citations and synonymy are easily available in Christensen's work, they are not repeated. All the specimens cited are in the U. S. National Herbarium, except the type of *Dryopteris tatei*.

KEY

Segments not ciliate; costae beneath puberulous with stellately fasciculate hairs; costae above short-pilosulous; auriculiform basal pinnae present; indusia present.

Segments entire or rarely crenulate toward apex; abortive basal pinnae numerous.

Leaf surface with red glands beneath.....1. *D. stuebelii*.

Leaf surface without red glands beneath.

Segments obtuse; indusium pilosulous.

Costae minutely puberulous beneath; sori medial or inframedial *D. cañadasii*

[1] Published by permission of the Secretary of the Smithsonian Institution. Received October 3, 1938.

[2] Dansk Vidensk. Selsk. Skr. VII. 10: 157–161. 1913.

Costae pilosulous beneath; sori distinctly supramedial
3. *D. andina.*

Segments acute; indusium glandular; sori supramedial
4. *D. macradenia.*

Segments serrate; abortive basal pinnae few.....5. *D. boliviensis.*

Segments long-ciliate; costae beneath puberulous or pilosulous with simple hairs; costae above antrorsely long-pilose; auriculiform basal pinnae absent; indusia absent.

Aerophores at base of costules absent.....6. *D. mapiriensis.*

Aerophores at base of costules present.

Costules with long, spinose hairs above.

Costae, costules, and veins minutely puberulous beneath, the hairs less than 0.25 mm long; red glands present ; veins 21–48 pairs.

Veins 29–48 pairs; segments 60 to 80 pairs; veins glabrous above
7. *D. decussata.*

Veins 21–27 pairs; segments about 50 pairs; veins with a few hairs above.....7a. *D. decussata* f. *velutina.*

Costae, costules, and veins long-pilose beneath, the hairs 0.5–3 mm long; red glands absent; veins 11–20 pairs.....8. *D. comosa.*

Costules glabrous above. Red glands absent.

Pinnae 5–7 cm wide, the segments 6–7 mm wide..9. *D. polyphlebia.*

Pinnae 2.5–4.5 cm wide, the segments 3.5–4 mm wide.

Receptacle elongate; veins of larger segments about 50 pairs, about 18 per cm.....10. *D. brasiliensis.*

Receptacle not elongate; veins 19–27 pairs, 12 to 15 per cm
11. *D. tatei.*

1. DRYOPTERIS STUEBELII Hieron.

The name *D. thomsonii* (Jenm.) C. Chr. used for this species by Christensen is a later homonym of *D. thomsonii* Kuntze and is consequently invalid. This species is common in Jamaica and is known also from Hispaniola. The South American specimens examined are:

COLOMBIA: Road from Pamplona to Toledo, Dept. Norte de Santander, alt. 2800–3000 meters, *Killip & Smith* 19971. Eastern páramos of Guasca, toward Gachetá, *Ariste-Joseph* s. n.

2. DRYOPTERIS CAÑADASII (Sod.) C. Chr.

Known definitely only from Ecuador. We have seen a specimen collected at Palmira by A. Mille at an altitude of 2600 meters. The following two collections perhaps represent forms of this species, but differ in smaller size and fewer veins: Monte Lirio, Río Chiriquí Viejo, Panama, *Seibert* 185; Mito, Peru, *Macbride & Featherstone* 1618.

3. **Dryopteris andina** Morton, sp. nov.

Rhizoma elongatum; stipites straminei, inermes, puberuli; lamina lanceolata, pinnis ligulatis (basalibus glanduliformibus numerosis), membra-

naceis, costa subtus pilosula, pilis stellato-fasciculatis, segmentis oblongis, rotundatis, eciliatis, integris, margine revolutis, supra scaberulis, subtus in costulis et venis puberulis, in mesophyllo eglandulosis; venae 14- vel 15-jugae, simplices; sori supramediales; indusia minuta, longe ciliata.

Rhizome elongate, sparingly palaeceous with large, flat, brown, dull, glabrous scales, the persistent stipe-bases about 10 cm long; fronds erect, about 1.4 m long, the stipes about 50 cm long, bisulcate on upper side, stramineous, not spiny, deciduously subappressed-puberulous, densely and persistently palaeceous at base, the scales large, dark brown, dull, glabrous, entire; blade lanceolate, about 90 cm long and 30 cm wide, the rachis puberulous with stellately fasciculate hairs; pinnae about 40 pairs, the basal 2 or 3 abruptly reduced (abortive glanduliform pinnae extending almost to base of stipe), alternate or subopposite, ligulate, up to 15 cm long and 2.3 cm wide, the costa above puberulous, beneath pilosulous with stellately fasciculate hairs, with longer hairs up to 0.5 mm long intermixed, bearing at base a slender aerophore about 6 mm long; segments about 40 below the subentire apex, 10–11 mm long, 2.5–3 mm wide, the apex rounded, the margin entire, not ciliate, revolute, the costules, veins, and leaf surface above sparingly scaberulous, the costules and veins beneath puberulous, eglandular, lacking aerophores at the base of the costules, the leaf surface with a few, scattered, simple hairs, not red-glandular; veins 14 or 15 pairs, simple; sori distinctly supramedial throughout and partially hidden by the revolute margins, the receptacle a little elongate; indusium persistent, minute, long-ciliate; annulus 15-articulate; spores about 44μ long.

Type in the U. S. National Herbarium, nos. 1,694,885–6, collected at Hacienda Sailapata, Department of Cochabamba, Bolivia, altitude 2800 meters, December, 1935, by M. Cárdenas (no. 3145).

Most nearly related to *D. cañadasii*, from which it differs in its pilosulous rather than closely puberulous costae and costules beneath, and in its distinctly supramedial sori.

4. DRYOPTERIS MACRADENIA (Sod.) C. Chr.

There is in the National Herbarium a specimen collected by Sodiro on the road from Quito to Manabi and labeled *Nephrodium macradenium* Sod., n. sp. It was collected, however, in 1903 and is therefore, not part of the type material. In fact, the specimen disagrees with the original description in having obtuse segments and inframedial sori, and is doubtless to be referred to *D. cañadasii*.

5. **Dryopteris boliviensis** Morton, sp. nov.

Stipites puberuli, mox glabrati, inermes; lamina oblongo-lanceolata, pinnis ligulatis (basalibus glanduliformibus paucis), membranaceis, costa subtus pilosula, pilis stellato-fasciculatis, segmentis anguste oblongis, rotundatis, eciliatis, medio serratis, margine revolutis, supra scaberulis, subtus in costulis et venis stellato-puberulis, in mesophyllo parce puberulis, parce rubro-glandulosis; venae 18- vel 19-jugae, simplices; sori mediales; indusia persistentia, pilosula.

Frond about 1.5 m long, the stipe probably about 50 cm long, stramineous, puberulous, soon glabrate, not spiny, epaleaceous except at base; blade oblong-lanceolate, about 1 m long, about 46 cm wide, the rhachis pilosulous;

pinnae about 37 pairs, the basal ones a little reduced (abortive glanduliform pinnae one pair), alternate, ligulate, the larger 23 cm long and 3.6 cm wide, the costa pilosulous above, beneath pilosulous with stellately fasciculate hairs, the basal aerophores small; segments about 40 pairs below the subentire apex, narrowly oblong, up to 18 mm long and 3 mm wide, the sinuses broad, the apex rounded, the margins not ciliate, those of the larger segments serrate at the middle, subentire toward base and apex, slightly revolute, the costules, veins, and leaf surface scaberulous above, the costules and veins stellate-puberulous beneath, eglandular, the basal aerophores reduced to glands, the leaf surface with a few, short, simple hairs and a few, small, red glands; veins 18 or 19 pairs, simple; sori medial, the receptacle scarcely elongate; indusia persistent, pilosulous and glandular; annulus 13- or 14-articulate; spores about 45μ long.

Type in the U. S. National Herbarium, nos. 1,618,895–6, collected at Sailapata, Department of Cochabamba, Bolivia, altitude 2600 meters, January, 1935, by M. Cárdenas (no. 3077).

In its serrate segments, the present species differs from all other members of the section *Glaphyropteris*, in which the segments are entirely or rarely a little crenulate at apex. The few abortive glanduliform basal pinnae well distinguish it in its group.

6. DRYOPTERIS MAPIRIENSIS Rosenst.

This Bolivian species is known only from the type collection, *Buchtien* 1131 from Mapiri, Bolivia. It is distinguished from all other members of *Glaphyropteris* by the absence of aerophores at the bases of the costules. The specimen of the original material in the National Herbarium is in poor condition.

7. DRYOPTERIS DECUSSATA (L.) Urban.

This well known species is common in the West Indies. The continental specimens, from Costa Rica to French Guiana, Ecuador, and Peru, are mostly if not all to be referred to f. *velutina* (Sod.) C. Chr., which may represent a valid species.

8. **Dryopteris comosa** Morton, sp. nov.

Stipites brunnei, puberuli, plus minusve aculeati; lamina oblongo-lanceolata, pinnis ligulatis (basalibus glanduliformibus nullis), costa supra pilosa, subtus longe pilosa, eglandulosa, segmentis anguste oblongis, rotundatis, longe ciliatis, supra in costulis et venis hirtis, subtus longe pilosis, eglandulosis; venae 11–20-jugae, 16–18 per cm; sori proxima supramediales, ceteri inframediales, exindusiati.

Rhizome massive, erect; fronds few, 60–100 cm long, the stipes 19 to 50 cm long, brown, shining, minutely puberulous, somewhat spiny, sparsely paleaceous, the scales light brown, membranous, glabrous, entire; blade oblong-lanceolate, 43–58 cm long, 20–29 cm wide, the rhachis puberulous and long-pilose, the pinnae 27–30 pairs, subopposite below, alternate upwardly, the basal 2 pairs slightly or strongly reduced (auriculiform basal pinnae absent), all ligulate, the larger 17 cm long and 2.5 cm wide, the costae above antrorsely pilose, beneath long-pilose, the hairs 1–3 mm long, minute hairs

and glands absent; segments about 40 pairs below the acuminate entire apex, narrowly oblong, 15 mm long or less, about 3.5 mm wide, the sinuses rather broad, the apices rounded, the margin ciliate, entire, the costules and veins above with long, stiff hairs, the costules and veins beneath pilose with long hairs, short hairs and glands absent; veins 11–20 pairs, simple, 16–18 per cm; sori supramedial toward base of segments, inframedial toward apex (immature in specimen examined).

Type in the U. S. National Herbarium, no. 1,694,884, collected at Dos de Mayo, Pichis Trail, Department of Junín, Peru, altitude 1700–1900 meters, July 3, 1929, by E. P. Killip and A. C. Smith (no. 25872).

This is a most distinct species, easily recognizable by its small size and few veins, and especially by the long, soft pubescence of the costae, costules, and veins beneath.

9. DRYOPTERIS POLYPHLEBIA C. Chr.

Described from the Andes of Quito. It is found also at low altitudes in Costa Rica, but has not been recently collected.

10. **Dryopteris brasiliensis** (C. Chr.) Morton, comb. nov.

Dryopteris decussata var. *brasiliensis* C. Chr. Dansk. Vidensk. Selsk. Skr. VII. **10**: 161. 1913.

Stipe rather densely paleaceous, bearing numerous spinelike processes, long-pilose in lower part; larger pinnae ligulate, 37 cm long, 4.5 cm wide, the segments over 70 pairs, up to 23 mm long and 4 mm wide, the sinuses broad, the margins ciliate, the upper surface and veins glabrous, costae antrorsely pilose above, sparingly short-puberulous beneath with simple hairs, eglandular, costules and veins beneath pilosulous, eglandular, leaf surface beneath glabrous eglandular; veins of larger segments about 50 pairs, close, about 18 per cm; sori in well developed pinnae supramedial, exindusiate, the receptacle distinctly elongate.

Type collected at Joinville, State of Santa Catharina, Brazil, in 1906, by E. O. Müller (no. 103).

11. **Dryopteris tatei** Maxon & Morton, sp. nov.

Stipites parce aculeati, longe pilosi; lamina oblongo-lanceolata, pinnato-pinnatifida, pinnis ligulatis (basalibus glanduliformibus nullis), costa supra longe pilosa, subtus puberula, pilis simplicibus, segmentis integris, longe ciliatis, rotundatis, supra glabris, subtus in costulis pilosulis; venae 19–27-jugae, simplices, 12–15 per cm; sori mediales vel supramediales, exindusiati, receptaculo non elongato.

Stipe up to 1.3 m long, dark brown, deeply bisulcate on upper side, rather strongly paleaceous in lower half (the scales pale brown, dull, thin, lanceolate, about 5 mm long, entire, glabrous), bearing spinelike processes either in lower half or toward apex, conspicuously pilose in lower half, the hairs straight, slender, whitish, simple, eglandular; blade over 60 cm long, oblong-lanceolate, pinnate-pinnatifid, the rachis epaleaceous, closely but minutely puberulous; pinnae more than 20 pairs, subopposite, sessile throughout, ligulate, the larger 19 to 23 cm long and 2.5–3.5 cm broad, antrorsely curved, the lower retrorsely curved, scarcely reduced (basal auriculiform pinnae none), all pinnately parted to within 1 mm of midrib, at apex linear and entire, the costa long-pilose above, puberulous beneath, the hairs simple; seg-

ments nearly horizontal, 40–50-jugate in the lower pinnae, narrowly oblong, the larger 14–20 mm long, 3.5–4 mm wide, rounded at apex, slightly broadened at base, papyraceous, dull green, entire, glabrous above, ciliate with long, white hairs, the costules conspicuously pilosulous beneath, the leaf surface bearing a few scattered hairs; aerophore at the base of the pinnae 4–8 mm long, persistent, the aerophores at the base of the costules subulate, about 0.5 mm long; veins 19–27-jugate, simple, free, 12–15 per cm, elevated above; sori medial or supramedial, exindusiate, the receptacle not elongate; sporangia relatively few, non-setose, the annulus 15-articulate; spores about 50μ long.

Type in the New York Botanical Garden, collected at Ticunhuaya, Cordillera Real, Bolivia, altitude 1500 meters, Apr. 20–24, 1926, by G. H. H. Tate (no. 1068). Fragment and photograph in the U. S. National Herbarium.

The most nearly related species is *Dryopteris decussata* (L.) Urban, of the West Indies, Guiana and Venezuela, which may be distinguished as follows:

Veins 19–21-jugate, 12–15 per cm; segments broadened at base, not close, not over 40 pairs; pinnae 19–23 cm long, 2.5–3 cm wide; stipe conspicuously pilose in lower half; leaf surface eglandular, more or less hairy; sori medial, the receptacle not elongate; costules glabrous above ..... *D. tatei.*

Veins 29–48-jugate, 17–23 per cm; segments hardly broadened at base, and therefore very close, sometimes even overlapping, 60–80 pairs; pinnae 25–45 cm long, 3–4.5 cm wide; stipe merely puberulous; leaf surface conspicuously red-glandular, glabrous; sori inframedial, the receptacle a little elongate; costules hairy above ..... *D. decussata.*

From *D. brasiliensis* the present species differs in its medial sori, smaller pinnae with fewer, smaller segments, and especially its fewer, more distant veins. In *D. brasiliensis* the veins of the larger pinnae are about 50-jugate.

BOTANY.—*A new taxonomic arrangement of the orange subfamily, Aurantioideae.*[1] WALTER T. SWINGLE, Bureau of Plant Industry.

I have been for the past three years engaged in a study of the wild relatives of Citrus and have prepared a synopsis of the tribes, subtribes and genera. This synopsis represents a new classification made possible by a prolonged and detailed study of all obtainable material of the 33 genera now included in the Orange subfamily. Many botanical institutions in Europe, Asia, Australia, Brazil and the United States of America have made generous loans of herbarium material which were supplemented by extensive collections made by me in China, Japan and the Philippines as well as in the United States during the past 25 years. In addition, what is probably the largest single collection in the world of living plants belonging to the Orange subfamily representing 25 out of the 33 genera, has been assembled from

[1] Received November 3, 1938.

many parts of the Old World and is now found in the Citrus greenhouses of the Bureau of Plant Industry at Washington, D. C. Most of these wild relatives of Citrus are also growing vigorously in the subtropical regions of Florida and California.

The herbarium material has been studied by restoring the flower buds, flowers and young fruits to as near their original fresh condition as possible by prolonged treatment with hot water, dilute ammonia and, in some cases, dilute hydrofluoric acid; then by using a modification of Juel's[2] method, serial microtome sections were made, stained and mounted permanently on glass slides. With the skillful assistance of Dr. A. H. Tillson more than 100,000 such sections have been made and in many cases they have enabled me to bring to light important new characters that have permitted a rational and, I believe, natural classification of the Orange subfamily including Citrus and its wild relatives. The tribes, subtribes and the 10 groups of genera that compose the three subtribes of the tribe Citreae will be discussed in another paper to appear later.

A NEW CLASSIFICATION OF THE ORANGE SUBFAMILY, AURANTIOIDEAE

Tribe 1. CLAUSENEAE

Subtribe 1. MICROMELINAE

1. *Micromelum* (9)

Subtribe 2. CLAUSENINAE

2. *Glycosmis* (35)
3. *Clausena* (29)
4. *Murraya* (10)

Subtribe 3. MERRILLINAE

5. *Merrillia*[*3]

Tribe 2. CITREAE

Subtribe 1. TRIPHASIINAE

6. *Wenzelia* (5)
7. *Monanthocitrus** — A *Wenzelia group.*
8. *Merope**

9. *Triphasia* (3) — B *Triphasia* group.
10. *Pamburus**

11. *Oxanthera* (3) — C *Oxanthera* group.

12. *Luvunga* (12) — D *Luvunga* group.
13. *Paramignya* (14)

Subtribe 2. CITRINAE

14. *Severinia* (8)
15. *Pleiospermium* (5)
16. *Burkillanthus** — A Primitive citrus fruit trees.
17. *Limnocitrus**
18. *Hesperethusa**

[2] JUEL, H. O. *Beiträge zur Blütenanatomie und zur Systematik der Rosaceen*, in Kungl. Svenska Vet. Handl. **58**:1–81, figs. 1–135, Stockholm, 1918.

[3] Genera marked with an asterisk are monotypic, i.e., have only one species.

19. *Citropsis* (11)	B	Near-citrus fruit trees.
20. *Atalantia* (9)		
21. *Fortunella* (4)	C	True citrus fruit trees.
22. *Eremocitrus**		
23. *Poncirus**		
24. *Clymenia**		
25. *Microcitrus* (6)		
26. *Citrus* (16)		

Subtribe 3. BALSAMOCITRINAE

27. *Swinglea**	A	Tabog group.
28. *Aegle**	B	Bael-fruit group.
29. *Afraegle* (4)		
30. *Aeglopsis**		
31. *Balsamocitrus**		
32. *Feronia**	C	Wood-apple group.
33. *Feroniella* (3)		

Totals: 2 tribes, 6 subtribes, 33 genera, 201 species, and 15 varieties.

In connection with the reclassification of this subfamily some transfers of species from one genus to another, as well as some allocations of species to varietal rank (and vice versa) have been necessary. These transfers are listed below. Three new genera, eight new species and three new varieties were also discovered and named; one old species had to be given a new name. They are also listed in proper order, but will be published in another paper.

LIST OF NEW GENERA, NEW SPECIES, NEW VARIETIES AND NEW COMBINATIONS.[4]

3. **Clausena dentata** var. **dulcis** (Bedd.), n. comb.
   Cookia ? *dulcis* Beddome, in Madras Journ. of Lit. and Sci. **22**: 70, 1861.
4. **Murraya alternans** (Kurz), n. comb.
   Limonia ? *alternans* Wall., in Voigt, Hort. suburb. Calcut. p. 139, 1845. Nomen nudum.
   Limonia alternifolia ("Wall. ap. Voigt") Kurz, in Journ. Asiat. Soc. Bengal **42**: 64, 1873.
   Limonia alternans (Wall.) Hook. f., Fl. Brit. India **1**: 508, 1875.
   Limonia alternans Kurz, For. Flora Burma p. 192, 1877.
   M. glabra (Guill.), n. comb.
   Micromelum glabrum Guillaumin, in Lecomte, Not. Syst. **1**: 216, 1910.
   M. stenocarpa (Drake), n. comb.
   Atalantia stenocarpa Drake, in Morot, Journ. Bot. **6**: 277, 1892.
6. **Wenzelia grandiflora** (Lauterb.), n. comb.
   Citrus grandiflora Lauterbach, in Nova Guinea **8**: 293, 1910.
   W. melanesica, n. sp., Solomon Islands.
   W. melanesica var. **morobeana**, n. var., New Guinea.
9. **Triphasia Brassii** (White), n. comb.
   Paramignya Brassii White, in Journ. Arn. Arboret. **7**: 231, 1926.

[4] The genera in this list are numbered as in the preceding outline of the new classification.

13. **Paramignya scandens** var. **Ridleyi** (Burk.) n. comb.
Paramignya Ridleyi Burkill, in Gard. Bull. Str. Settlem. **5**: 214, 1931.
P. scandens var. **hispida** (Pierre), n. comb.
Atalantia hispida Pierre ex Guill., in Lecomte, Not. Syst. **1**: 182, 1910.
P. hainanensis, n. sp., Hainan Island.
P. cuspidata (Ridl.), n. comb.
Atalantia cuspidata Ridley, in Journ. Asiat. Soc. Str. Branch No. **82**: 174, 1924.
14. **Severinia buxifolia** var. **brachitica**, n. var., China (?) Cult.
S. disticha (Blanco), n. comb.
Limonia disticha Blanco, Fl. Filip. p. 356, 1837.
S. linearis (Merr.), n. comb.
Atalantia linearis Merrill, in Philip. Journ. Sc. **1** (Suppl. 3): 200, 1906.
S. paniculata (Warb.), n. comb.
Atalantia paniculata Warburg, in Engl. Bot. Jahrb. **13**: 340, 1891.
S. retusa (Merr.), n. comb.
Atalantia retusa Merrill, in Philip. Journ. Sci. **1** (Suppl. 3): 200, 1906.
S. trimera (Oliv.), n. comb.
Atalantia trimera Oliver, in Journ. Linn. Soc. **5** (Suppl. 2): 24, 1861.
S. Lauterbachii, nomen nov.
Atalantia litoralis Lauterbach (non Guill. 1913), in Nova Guinea **14**: 146, 1924.
15. **Pleiospermium sumatranum**, n. sp., Sumatra.
P. longisepalum, n. sp., Banguey Island.
P. latialatum, n. sp., North Bornea.
16. **Burkillanthus malaccensis** (Ridl.), n. gen. and n. comb.
Citrus malaccensis Ridley, Flora Malay Penin. **1**: 359, 1922.
17. **Limnocitrus littoralis** (Miq.), n. gen. and n. comb.
Paramignya littoralis Miquel, in Ann. Mus. Lugd. Bat. **1**: 211, 1864.
19. **Citropsis latialata** (De Wild.) Swing. and M. Kell., n. comb.
Limonia Poggei var. *latialata* De Wildeman, in Ann. Mus. Congo, Bot. 5 sér. **1**: 160, 1904.
C. Gilletiana Swing. and M. Kell., n. sp., Belgian Congo.
C. gabonensis var. **Gentiliana** Swing. and M. Kell., n. var., Belgian Congo.
C. Daweana Swing. and M. Kell., n. sp., Portuguese East Africa.
C. Tanakae Swing. and M. Kell., n. sp., Sierra Leone.
21. **Fortunella Hindsii** var. **chintou**, n. var., China, Japan.
24. **Clymenia polyandra** (Tan.), n. gen. and n. comb.
Citrus polyandra Tanaka, in Studia Citrol. **2**: 163, 1928.
25. **Microcitrus Maideniana** (Domin), n. comb.
Citrus Maideniana Domin, in Bibl. Bot. No. **89**: 297, 1927.
26. **Citrus celebica** var. **Southwickii** (Wester), n. comb.
Citrus Southwickii Wester, in Philip. Agr. Rev. **8**: 16, 1915.
C. macroptera var. **Kerrii**, n. var., Siam.

ENTOMOLOGY.—*The genus* Chramesus *Leconte in North America (Coleoptera: Scolytidae).*[1] M. W. BLACKMAN, Bureau of Entomology and Plant Quarantine. (Communicated by C. F. W. MUESEBECK.)

The scolytid genus *Chramesus* Lec., although not known to include any species of primary economic importance, is of considerable interest both from biological and from taxonomic standpoints. The North American members of the genus breed entirely in deciduous trees and shrubs, utilizing only material which is severely injured, decadent, or dead. So far as is known none of the species ever successfully attacks parts of hosts which are in a vigorous condition, although bark still green and moist is usually preferred. Trees which serve as hosts of species of *Chramesus* in the United States are the hickories, hackberry, locust, oak, and mimosa.

Taxonomically, *Chramesus* has no close relatives in North America and can be instantly recognized by the structure of the antennae alone. Blandford (3) briefly discusses the question of the relationships of *Chramesus* and believes the most natural grouping is to place it near *Phloeotribus* Latreille. He also points out certain similarities in antennal structure with the genus *Eulytocerus* Bldfd. described (1897) from Panama. While Blandford is probably right, the relationship to *Phloeotribus* and *Eulytocerus* appears to be by no means close.

In 1909 Hagedorn (7) described *Chramesus acuteclavatus* from Argentina. This species while not a true *Chramesus* is closely related to that genus, as is indicated by the attachment of the large antennal club to the five-jointed funicle by its superior margin, and by numerous other similarities. However, *acuteclavatus* is fundamentally different from all species of true *Chramesus* in several respects and must be removed from that genus. The United States National Museum contains a good series of several closely related species from Argentina and Bolivia and the new genus to which they belong will be treated in a forthcoming paper. These facts are mentioned here because the undescribed genus represented by *C. acuteclavatus* Hagedorn appears to be either in the direct line of descent of *Chramesus* or is an offshoot from this line of descent. Undoubtedly it is much more closely related than either *Phloeotribus* or *Eulytocerus* or any other genus known at present.

The probable relationships discussed above lead us to suspect a tropical or subtropical origin for the genus *Chramesus*, and this idea

[1] Received September 23, 1938.

receives added support from the fact that only two of the eight species known to occur in this country, *C. hicoriae* Lec. and *C. chapuisii* Lec., have been found farther north than Louisiana and Arizona. Even though we know comparatively little of the bark-beetle fauna of Central and South America, seven species of *Chramesus* have been described from those regions and there is reason to believe that a number of species at present unknown to science occur there.

Genus **Chramesus** Leconte

Chramesus Leconte, Amer. Ent. Soc. Trans. **2**: 168. 1868; Leconte, Amer. Phil. Soc. Proc. **15**: 374. 1876 (redescription); Blandford, Biol. Centr.-Amer., Coleoptera **4** (6): 169. 1897; Swaine, N. Y. State Mus. Bul. **134**: 88. 1909; Hagedorn, Genera Insectorum, Coleoptera, fasc. **111**: 66. 1910; Hopkins, U. S. Natl. Mus. Proc., **48**: 118. 1914; Swaine, Dominion Ent. Branch, Dept. Agr. Bull. **14**: 58. 1917; Blackman, Miss. Agr. Expt. Sta. Tech. Bull **11**: 50. 1922. Bruck, Bull. So. Calif. Acad. Sci. 35,141,123, 1936 (Genotype, *Chramesus hicoriae* Leconte, monobasic.)

Rhopalopleurus Chapuis, Mem. Soc. Sci. Liege, Ser. 2, **3**: 255. 1873. (Author's extract issued 1869 p. 46); Leconte, Amer. Phil. Soc. Proc. **15**: 374. 1876 (=*Chramesus*).

Body stout, oval, convex, ornamented with hairs, stout bristles, and scales; *head* with the beak very short; frons convex in the female, concave in the male; eyes elongate oval, entire; antenna with the scape long, the funicle 5-jointed, attached at the upper margin of the club, which is very large, flattened, and unsegmented; *pronotum* short, much wider than long, asperate on the sides of the disk, the posterior outline bisinuate, extended in the median area; dorsal outline of *elytra* oblique, with the declivity but slightly more arcuate, and the bases strongly crenate, the vestiture consisting of stout bristles and short scale-like hairs.

The genus *Chramesus* forms a very compact group, easily recognized from other more or less closely related genera by the characters given above. The antennal structure is especially distinctive, and alone serves to distinguish *Chramesus* from all other scolytid genera.

The antennal characters are also of value in dividing the genus into primary divisions. One group containing *hicoriae*, *asperatus*, *subopacus*, *canus*, and *gibber*, which has a very large, more slender antennal club and the scape with only a few hairs in either sex, is readily separated from the group containing *chapuisii*, *dentatus*, and *mimosae*, which has a smaller and broader antennal club, and has the scape in the male at least, ornamented with a beard of long hairs.

The further subdivision of the genus into species is dependent upon the size and proportions of the body; the shape, sculpture, and vestiture of the pronotum; the form, sculpture, and vestiture of the frons; the punctation and width of the striae; the vestiture of the interspaces, etc.

In addition to the North American species mentioned in an earlier paragraph which are later treated in detail, eight species have been described from outside the borders of the United States.

Chapuis (4), in 1869, described (*Rhopalopleurus*) *Chramesus tuberculatus*, *rotundatus*, and *pumilus* from New Grenada, Guadeloupe, and Teapa, Mexico, respectively.

Blandford (3), in 1897, described *Chramesus tumidulus* from Guatemala.

Hagedorn (7) in 1909 described *Chramesus globosus* and *C. acuteclavatus* from Argentina. The latter is not a *Chramesus*.

Stebbing (18) described *Chramesus globulus* from India in 1914. On the evidence furnished by the description and figures, it should be excluded from *Chramesus* and seems to be more closely allied to *Sphaerotrypes* Blandford.

Eggers (5) described *C. barbatus* from Mexico in 1930.

KEY TO THE NORTH AMERICAN SPECIES OF CHRAMESUS LEC.

A. Antennal scape without a tuft of long hairs in either sex; club very large, rather slender, more than 2.5 times as long as wide.
  B. Pronotal disc opaque or subopaque, moderately to strongly asperate at the sides, the posterior margin moderately to strongly produced in median area.
    C. Less than 2.0 mm long; pronotum with posterior margin rather strongly produced, median area of disc granulate-punctate, vestiture hairlike; elytral interspaces with median row of rather long, slender, erect bristles.
      D. Pronotum less strongly sculptured; elytral striae slightly narrower, with fine, moderately close punctures; Eastern States, in *Hicoria*. . . . . *hicoriae* Leconte
      DD. Pronotum more strongly sculptured; elytral striae wider, with the punctures closer and slightly coarser; Southwestern States, in *Robinia*. . . . . *asperatus* Schaeffer
    CC. More than 2.25 mm long; pronotum with posterior margin moderately produced, median area of disc punctured, vestiture more scalelike; elytral interspaces with median row of bristles shorter and stouter.
      D. Pronotum less than 1.3 times as wide as long; elytral striae very narrow, the punctures very fine and inconspicuous; frons in female without a median fovea. . . . . *subopacus* Schaeffer
      DD. Pronotum more than 1.3 times as wide as long; elytral striae much wider, the punctures much coarser and distinct; the frons in female with a median fovea. . . . . *canus*, new species
  BB. Pronotal disc shining, very sparsely asperate at the sides, the posterior margin rather weakly produced. . . . . *gibber*, new species
AA. Antennal scape with a tuft of long hairs in the male at least; the club smaller and broader, less than 2.25 times as long as wide.
  B. Female frons with median fovea, scanty fine hairs, no epistomal tooth; male frons concave, with a tooth on each lateral margin; antennal scape with a tuft of long hairs in the male only; elytral interspaces wide and striae narrow. . . . . *chapuisii* Leconte

BB. Female frons with or without fovea, with a median epistomal tooth, the hairs stouter; male frons concave, with a median epistomal tooth and none at the sides; antennal scape bearded in the male or in both sexes; elytral interspaces narrower and striae wider.

C. Antennal scape bearded in the male only; female frons with a median fovea; vestiture concolorous..... *dentatus* Schaeffer

CC. Antennal scape bearded in both sexes; female frons devoid of a median fovea; vestiture bicolorous..... *mimosae*, new species

Chramesus hicoriae *Leconte*

Chramesus hicoriae Leconte, Amer. Ent. Soc. Trans. **2**: 168, 178. 1868; Felt, N. Y. State Mus. Mem. **8** (2): 448. 1906; Swaine, N. Y. State Mus. Bull. **134**: 88. 1909; Blackman, Miss. Agr. Expt. Sta. Tech. Bull. **11**, p. 50. 1922; Blackman, N. Y. State Col. Forestry Tech. Bull. **17**, p. 143. 1924 (biology); Leonard et al., Cornell Univ. Agr. Expt. Sta. Mem. **101**, p. 515. 1928.

Chramesus icoriae Leconte, Amer. Phil. Soc. Proc. **15**: 375. 1876; Hubbard & Schwarz, Amer. Phil. Soc. Proc. **17**: 666. 1878 (Michigan); Packard, U. S. Ent. Comn. 5th Rept., p. 296. 1890; Hopkins, W. Va. Agr. Expt. Sta. Bull. **31**, p. 140; **32**: 212. 1893; Hopkins, Canad. Ent. **26**: 280. 1895; Blandford, Biol. Centr.-Amer., Coleoptera Pt. 6, p. 170. 1897; Smith, Rept. Ins. N. J., p. 403. 1910; Swaine, Dominion Ent. Branch Dept. Agr. Bull. **14** (2), p. 58. 1918.

Rhopalopleurus lecontei Chapuis, Ext. Mem. Soc. Sci. Liege. (2), **3**, p. 46. 1869; Leconte, Amer. Phil. Soc. Proc. **15**: 375. 1876 (=*C. icoriae* Lec.).

Female.—Varying from brown to piceous black in color, with cinereous bristles and scales; 1.5 to 1.9 mm long, about 1.65 times as long as wide.

Frons flattened, subopaque to feebly shining, with an arcuate, feebly elevated line between the bases of the antennae, finely, rather obscurely punctured, with a few short, fine, reclinate hairs. *Eye* large, elongate oval, rather coarsely granulate, the inner line not emarginate. *Antenna* yellow, the scape long, slender, without long hairs; pedicel irregularly urn-shaped, enlarged ventrally; the club large, about 2.65 times as long as wide, with the 5-jointed funicle attached at its upper margin (Fig. 3).

Pronotum about 1.33 times as wide as long;[2] the posterior outline bisinuate, moderately produced in the median line; sides arcuate and strongly converging anteriorly, moderately broadly rounded in front, feebly, transversely impressed just behind front margin; surface subopaque, the disc moderately granulate-punctate in median area, the lateral areas rather strongly asperate; sides granulate-punctate; the entire surface moderately clothed with rather coarse, subreclinate, cinereous bristles, directed postero-mesially on the disc.

Elytra distinctly wider than pronotum, about 1.12 times as long as wide; the bases separately arcuate, the margins elevated and serrate; sides feebly arcuate, subparallel on the anterior half, broadly rounded behind; dorsal outline arcuate and obliquely descending from the base; the surface opaque; the striae narrow, impressed, moderately shining, with fine, moderately closely placed punctures; interspaces wider, subconvex, with a sparse median row of granules, from the base of each of which arises an erect, stout

[2] Measurements of the pronota of this and the other species were made from a point perpendicular to their centers. This is to avoid the variable foreshortening due to differences in the angle of vision.

bristle; sides of interspaces and intervals between granules finely punctured and bearing short, stout, reclinate scalelike hairs. Declivity oblique, arcuate, unmodified.

Male.—Similar in habitus but readily distinguished by the character of the frons, which has a strong concavity, longer than wide, and bordered on each side by a sharp elevated margin, usually with a sharp toothlike projection just below the level of each antennal insertion.

This species was described by Leconte from specimens obtained from hickory twigs in Pennsylvania. The writer has studied specimens from New York, New Jersey, Pennsylvania, Maryland, the District of Columbia, West Virginia, Virginia, North Carolina, Georgia, and Mississippi. It is also reported from eastern Canada by Swaine. All specimens studied were obtained from twigs of various species of *Hicoria*.

Chramesus asperatus Schaeffer

Chramesus asperatus Schaeffer, N. Y. Ent. Soc. Jour. **16**: 220. 1908. Bruck, Bull. So. Calif. Acad. Sci. **35**: 125. 1936.

Female.—Dark reddish-brown to piceous; 1.97 mm long, about 1.6 times as long as wide.

Frons feebly convex, transversely impressed below, arcuately elevated between the antennae, slightly flattened just above; surface moderately shining, very finely punctured, with inconspicuous, fine, short hairs. *Eye* narrow, elongate oval, moderately granulate, the inner line entire. *Antenna* testaceous, the scape long, slender, devoid of long hairs; the club nearly three times as long as wide (Fig. 2).

Pronotum obliquely descending from its base, actually 1.35 times as wide as long, but appearing shorter in dorsal view; posterior outline bisinuate, rather strongly extended at median line; sides arcuate and strongly converging anteriorly, moderately rounded in front, somewhat impressed just behind the front margin; surface rather shining, the disc asperate throughout except in the middle half of the median longitudinal line, which is slightly elevated, shining and devoid of punctures, hairs, and granules, the asperities stronger at the sides of the disc; sides granulate-punctate; the entire surface, except median line, clothed with thickened, semierect, cinereous bristles of medium length.

Elytra distinctly wider than pronotum, about 1.11 times as long as wide, the bases separately arcuate, the margins elevated and strongly serrate; the sides subparallel, moderately broadly rounded behind; dorsal outline arcuate, less oblique than in *hicoriae;* surface subopaque; striae rather narrow, distinctly impressed, the punctures fine and close; interspaces rather wide, subconvex, uniserially granulate-punctate, each with a median row of erect, stout bristles and at each side a row of small, rather narrow, reclinate scales. Declivity unmodified.

Male.—Pronotum more strongly, transversely impressed in front, the smooth median longitudinal line almost lacking, the front of the head shiny, broadly, rather deeply concave, with the margins rather sharply elevated and with a small tooth at each side opposite the insertion of the antenna.

Schaeffer described this species from a short series of specimens given to him by E. A. Schwarz, taken from a long series collected by H. G. Hubbard June 1–3, 1897, in Pine Canyon, Chiracahua Mts., Ariz. These were col-

lected in the twigs of *Robinia neo-mexicana*. The parent series contains 127 additional specimens. This is a common species in the twigs of *Robinia neo-mexicana* in Arizona. The writer has studied several hundred specimens from the Kaibab National Forest, Williams, Prescott, Santa Catalina Mts., Chiricahua Mts., and Huachuca Mts. The species as usual shows considerable individual variation in the degree of development of the frontal and antennal structures, and many specimens show little or no indication of the smooth longitudinal line of the pronotum.

Schaeffer's cotypes of this species were presented to the U. S. National Museum by the Brooklyn Museum. One of these cotypes, a female, is selected as the lectotype and the preceding description was taken from it.

Type locality.—Pine Canyon, Chiracahua Mts., Ariz.

Host.—*Robinia neo-mexicana* Gray.

Lectotype female, 2 male paratypes.—U. S. N. M., No. 42486.

Chramesus subopacus Schaeffer

Chramesus subopacus Schaeffer, N. Y. Ent. Soc. Jour. **16**: 221, 1908. Bruck. Bull. So. Calif. Acad. Sci. **35**: 124. 1936.

Female.—Dark brown, almost black; 2.29 mm long, 1.66 times as long as wide.

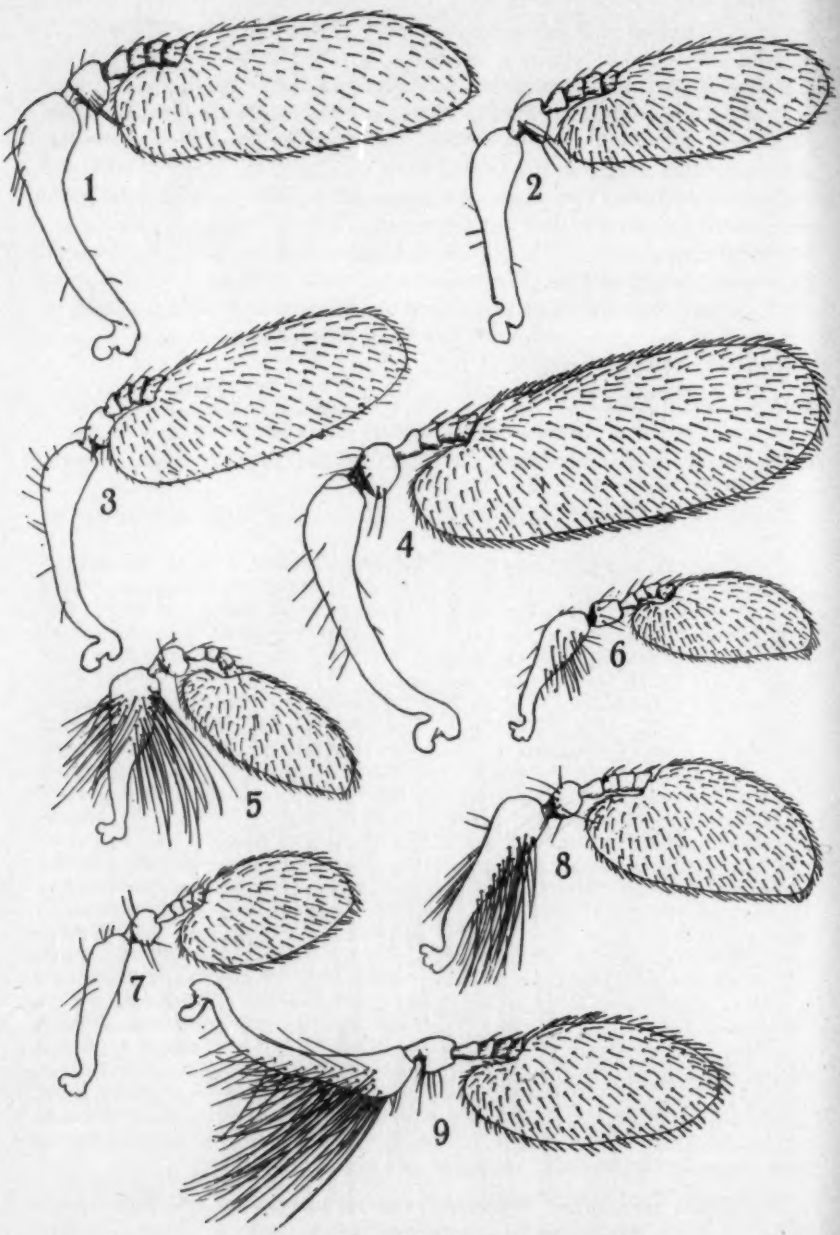
Frons convex, broadly transversely impressed below, with this broad impression bordered at each side by an elevated line; surface subopaque, finely granulate-punctate, with fine, short, inconspicuous, cinereous hairs. *Eye* large, elongate oval, coarsely granulate, the inner line entire. *Antenna* yellow, the scape long and slender, the pedicel with a protuberance; the club very large (Fig. 1), 2.70 times as long as wide.

Pronotum 1.28 times as wide as long, the posterior outline bisinuate, moderately produced in the median line, sides arcuate and strongly converging anteriorly, broadly rounded in front, transversely impressed just behind the front margin; surface subopaque, the disc granulate-punctate, more finely and closely than in *hicoriae*, the lateral areas more sparsely asperate; sides granulate-punctate; the entire surface clothed with appressed, cinereous scales varying from two to three times as long as wide.

Elytra distinctly wider than pronotum, about 1.12 times as long as wide; the bases separately arcuate, the margins moderately elevated, moderately serrate; sides subparallel on more than the basal half, very broadly rounded behind; dorsal outline more strongly arcuate and less oblique than in *hicoriae;* surface opaque; the striae very narrow, moderately strongly impressed, with very fine punctures, separated by as much as, or more than, their own diameter; interspaces much wider, feebly convex, with a median row of very fine punctures bearing suberect, spatulate bristles, the remainder of each interspace rather densely clothed with short, broad, appressed, cinereous scales. Declivity unmodified, the interspaces devoid of granules as on the disc.

Male.—Frons deeply concave, with the surface shining, very finely punctured, and with sparse, short, very fine, reclinate, cinereous hairs, the side of the concavity bordered by a raised margin which on the anterior half is very strongly elevated and extended to form a sharp ridge.

The writer has studied 30 specimens of this species, of which two specimens, a male and a female, are Schaeffer's cotypes received from the



FIGS. 1–9.—For explanation see opposite page.

Brooklyn Museum. Twenty-eight additional specimens were bred from wood of *Celtis*, taken at San Antonio, and La Grange, Tex., by W. F. Fiske in 1907. The female cotype has been selected as the lectotype.

Type locality.—Huachuca Mts., Ariz.

Additional localities.—San Antonio and La Grange, Tex.

Host.—*Celtis.*

Lectotype female and 1 male paratype.—U. S. N. M., No. 42934.

Chramesus canus, n. sp.

Female.—Brown with grayish vestiture; 2.5 mm long, 1.66 times as long as wide. Closely allied to *Chramesus subopacus* Schaeffer.

Frons transversely impressed below, the impression bordered at each side by an elevated ridge, with an arcuate elevation between the bases of the antennae, convex above, with a distinct, large fovea in the median line just above the arcuate elevation; surface subopaque, very finely and closely granulate-punctate, with very fine, cinereous hairs, scarcely visible except in profile. *Eye* elongate oval, rather finely granulate, the inner line entire. *Antennal club* very large, 2.8 times as long as wide (Fig. 4).

Pronotum 1.3 times as wide as long; the posterior margin bisinuate, moderately produced in the median line; sides arcuate and converging strongly anteriorly, broadly rounded in front, feebly impressed behind the front margin; surface subopaque; disc with the median area finely, moderately closely punctate, scarcely granulate, the lateral areas more strongly asperate than in *subopacus;* sides finely granulate-punctate; the surface clothed with appressed scales which are rather more slender than in *subopacus.*

Elytra wider than pronotum, similar to *subopacus* in form and proportions, but with the basal margin more strongly elevated; the striae wider and with coarser punctures; the discal interspaces slightly flatter, each with a median row of fine granules and a row of suberect, spatulate, rather short bristles, inconspicuous except in profile; appressed scales large and rather slender.

Male.—Frons with the usual secondary sexual differences and differing from that of *subopacus* in the concavity being slightly narrower and deeper and the marginal ridge somewhat thicker.

Type locality.—Tallulah, La.

Host.—Unknown.

Holotype female, allotype, and 1 male and 1 female paratype.—U. S. N. M., No. 43841.

The holotype, allotype, and two paratypes bear the data—"Tallulah, La., 2-6-11; Hunter, No. 1984; G. D. Smith, Collector."

Chramesus gibber, n. sp.

Female.—Yellowish brown (immature); 2.0 mm long, 1.66 times as long as wide.

Fig. 1.—Antenna of *Chramesus subopacus* Schaeffer, male; Fig. 2.—Antenna of *C. asperatus* Schaeffer, female; Fig. 3.—Antenna of *C. hicoriae* Leconte, female; Fig. 4.—Antenna of *C. canus*, n. sp., female; Fig. 5.—Antenna of *C. mimosae*, n. sp., male; Fig. 6.—Antenna of *C. mimosae*, n. sp., female; Fig. 7.—Antenna of *C. dentatus* Schaeffer, female; Fig. 8.—Antenna of *C. dentatus* Schaeffer, male; Fig. 9.—Antenna of *C. chapuisii* Leconte, male.

Frons somewhat flattened, transversely impressed below, with an arcuate transverse elevation between the bases of the antennae; surface moderately shining, very finely punctured, and with very fine, short, inconspicuous hairs. *Eye* elongate oval, finely granulate, the inner margin entire. *Antenna* testaceous, the scape long and rather slender; the club moderately large, 2.36 times as long as wide.

Pronotum 1.34 times as wide as long, posterior outline bisinuate, weakly produced in the median region; sides arcuate, moderately strongly converging anteriorly, transversely impressed just behind the broadly rounded front margin; surface shining; median area of disc moderately punctured (more coarsely than in *hicoriae*) and without granules, lateral areas of disc sparsely, not strongly, asperate; sides moderately punctured; sides and disc rather sparsely clothed with rather short, stiff, moderately stout, semierect setae.

Elytra wider than pronotum, 1.07 times as long as wide; sides subparallel, broadly rounded behind; basal margins separately arcuate, strongly elevated and crenate; dorsal outline oblique, the declivity strongly arcuate; surface rather shining; the striae narrow, moderately impressed, the punctures deep, fine, separated by their own diameter or more; interspaces wide, weakly convex, devoid of granules, each with a median row of erect, spatulate bristles of moderate length, the surface sparsely clothed with rather slender, appressed scales. Declivity unmodified except that the strial punctures are finer and both striae and interspaces narrower.

Male.—Frons deeply, broadly concave, the side margins sharply elevated below, with a low tooth just mesad and ventrad of each antennal insertion; the antennal scape with a few hairs of moderate length not forming a tuft.

Type locality.—Cloudcroft, N. M.

Host.—*Robinia.*

Holotype female, allotype and 1 male paraytpe.—U. S. N. M., Mo. 43842.

The holotype, allotype, and paratype bear the data—"Hopk. U.S. 7208; W. F. Fiske, Collector; Cloudcroft, N. M., *Robinia.*"

Chramesus chapuisii Leconte

Chramesus chapuisii Leconte, Amer. Phil. Soc. Proc. **15**: 375. 1876; Schwarz, Ent. Amer. **2**: 54. 1886; Blackman, Miss. Agr. Expt. Sta. Tech. Bull. 11, p. 51, 1922.

Female.—Piceous to black in color; 1.48 to 1.97 mm long, 1.7 times as long as wide.

Frons convex, transversely impressed below, with a transverse, arcuate elevation between the bases of the antennae, and with a small but distinct pit or fovea in the median line just above it; surface subopaque, reticulate, with rather sparse, very fine punctures and scanty, rather short, appressed hairs. *Eye* elongate oval, rather coarsely granulate, the inner line entire. *Antenna* testaceous, the scape rather long and slender, with a few hairs of moderate length; the club little more than twice as long as wide (Fig. 9).

Pronotum 1.33 times as wide as long; posterior outline bisinuate, not strongly extended at the median line; the sides arcuate, rather strongly converging anteriorly, very feebly transversely impressed, moderately broadly rounded in front; surface subopaque, disc granulate-punctate in the median area, the lateral areas moderately strongly asperate; sides finely granulate-punctate; vestiture on sides and disc consisting of cinereous, spatulate-hairs, the latter slightly more slender in median area of disc.

Elytra wider than pronotum, about 1.12 times as long as wide; the sides subparallel, moderately rounded behind; anterior margins separately arcuate, elevated and strongly crenate; dorsal outline not strongly oblique, moderately strongly arcuate on the declivity; surface subopaque; striae rather narrow, moderately impressed, with fine, closely placed punctures; interspaces about four times as wide as striae, feebly convex, each with a median row of erect spatulate hairs, rather densely clothed with small, nearly circular, appressed, cinereous scales, the first three interspaces with a sparse, median row of small granules.

Male.—Similar in size and habitus, but with the frons concave, bordered at each side by a distinct carina which is elevated to form a small, sharp tooth just ventrad of each antennal insertion; the antennal scape with a tuft of long cinereous hairs.

This species breeds in hackberry and occurs in the Southeastern States. The writer has studied specimens from Texas, Louisiana (the type locality), Mississippi, Florida, Maryland, Pennsylvania, and Kansas. The Maryland specimens are from Plummers Island. All specimens were taken from *Celtis*.

Chramesus dentatus Schaeffer

Chramesus dentatus Schaeffer, N. Y. Ent. Soc. Jour. **16**: 221. 1908. Bruck. Bull. So. Calif. Acad. Sci. **35**: 124. 1936.

Female.—Dark reddish brown, 1.74 mm long, 1.78 times as long as wide. *Frons* feebly convex; surface reticulate, subopaque; finely, rather sparsely punctured, with short, stout, scalelike hairs; with a small, toothlike epistomal process, and above it, in the median line, a small fovea. *Eye* elongate oval, rather finely granulate, the inner margin entire. *Antenna* paler in color, the scape slightly widened distally, with a few rather short hairs, not forming a tuft; the club much smaller and wider than usual, scarcely twice as long as wide, the distal end subacute (Fig. 7).

Pronotum 1.22 times as wide as long, obliquely descending from the base; posterior outline bisinuate, scarcely extended in the median line; sides arcuate, converging anteriorly; moderately transversely impressed just behind the front margin; surface subopaque, disc with the median area granulate-punctate, elevated in the median line on the posterior half; lateral areas of disc sparsely, rather finely asperate; sides more shining, granulate-punctate; the entire surface clothed with small, subreclinate, scalelike, yellowish-brown hairs.

Elytra distinctly wider than pronotum, 1.2 times as long as wide; the sides subparallel, broadly rounded behind; anterior margins separately arcuate, elevated and finely crenate; dorsal outline only slightly oblique, strongly arcuate on the declivity; surface subopaque; striae wider than in any of the preceding species, rather feebly impressed, the punctures of moderate size, separated by less than their own width; interspaces narrower than in preceding species, subconvex, with a median row of small punctures, bearing short, stout, suberect bristles and with very small, appressed scales rather sparsely covering the interspaces and occasionally arising from the striae between the punctures.

Male.—Frons broadly, moderately deeply concave, with the margins not sharply elevated, the surface somewhat shining, finely reticulate, with sparse, fine punctures bearing appressed, moderately short, cinereous hairs; epistomal process elevated to form a sharp tooth; scape of antenna bearing a tuft of long hairs (Fig. 8).

The type series in the National Museum consists of three male cotypes and one female cotype bearing the data "Huach. Mts., Ariz." and the Brooklyn Museum Collection label. They were obtained from oak twigs girdled by *Oncideres quercus* Skinner. Three other specimens bear only the Brooklyn Museum labels, without further data, but seem to be mounted identically and probably are from the same original lot. The female cotype has been selected as the lectotype.

Type locality.—Huachuca Mts., Ariz.

Host.—*Quercus* sp.

Lectotype female and 3 male paratypes.—U. S. N. M., No. 42487.

Chramesus mimosae, n. sp.

Female.—Dark brown to piceous, with the elytra reddish brown basally; 1.57 mm long, 1.8 times as long as wide.

Frons flattened, very feebly concave between the eyes, the epistomal margin with a minute, sharp tooth; surface opaque, reticulate, with very fine punctures from which arise conspicuous, short, stout, appressed, scalelike, cinereous hairs; with a dense fringe of longer cinereous hairs extending from the epistomal margin nearly to the ends of the mandibles in front, and to about one-half of their length at the sides. *Eye* elongate oval, finely granulate, the inner line entire. *Antenna* testaceous, the scape moderately widened distally, with rather numerous moderately long hairs; the club scarcely more than twice as long as wide, the distal end subacute (Fig. 6).

Pronotum 1.25 times as wide as long, obliquely descending; posterior margin bisinuate, distinctly extended in the median line, sides arcuate, strongly converging in front of the center; moderately rounded in front and feebly transversely impressed just behind the front margin; surface opaque, feebly and sparsely asperate at sides of disc; median area very finely and rather closely punctured; entire surface clothed with closely placed, small, reclinate, cinereous, scalelike hairs.

Elytra wider than pronotum, about 1.23 times as long as wide; sides subparallel, rather broadly rounded behind; anterior margins separately arcuate, elevated and crenate; surface opaque; striae narrower than in *dentatus*, rather weakly impressed, the punctures fine and close; interspaces moderately wide, feebly convex, each with a sparse median row of moderately long, spatulate, cinereous bristles and rather closely arranged, appressed scales which are cinereous on the first interspace and on the sides and anterior disc, but light brown on second to fourth interspaces from basal third nearly to apices of elytra, the scales slightly larger and more slender than in *dentatus;* strial punctures at the sides larger than on the disc, interstrial bristles less numerous.

Male.—Frons broadly and rather deeply concave, with margins moderately but not sharply elevated, surface subopaque, reticulate, ornamented with appressed, cinereous hairs; epistomal margin with a small, sharp tooth; scape of antenna with a tuft of longer hairs (Fig. 5) much larger than in female.

Type locality.—Brownsville, Tex.

Other locality.—Monterrey, Mexico.

Host.—Mimosa (*Leucaena pulverulenta*)

Holotype, allotype, and 638 paratypes.—U. S. N. M., Mo. 52803.

The holotype, allotype and 637 paratypes were collected and bred from mimosa (*Leucaena pulverulenta*) at Brownsville, Tex., by H. S. Barber. A single paratype bears the labels "Monterrey, Mexico, 25.11; E. A. Schwarz collector."

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Obituary

WILLIS RAY GREGG, meteorologist and late Chief of the Weather Bureau, died in the Blackstone Hotel at Chicago, Ill., on Sept. 14, 1938. Dr. Gregg was born at Phoenix, New York, January 4, 1880. He received the B.A. degree from Cornell University in 1903, and was awarded the honorary degree of Sc.D. in 1937 by Norwich University. He entered the Weather Bureau on March 1, 1904 at Grand Rapids, Michigan. At the research laboratory at Mt. Weather, Va., where he served for seven years, he took part in important studies dealing with the upper air. In 1914 he was called to Washington, D.C. where he was Assistant Chief and later Chief of the Aerological Division, which not only promoted and carried out many technical studies pertaining to meteorology but was charged also with the problem of giving an adequate meteorological service to aviation which was in process of extremely rapid development and expansion.

This training and experience coupled with an untiring devotion to duty, equable temper, an inherent sense of fairness and keen mind, well-equipped him for the important position of Chief of the Weather Bureau to which he was appointed in January 1934. There is little doubt that his untiring devotion to the responsibilities of his office contributed to his untimely demise.

He was a member of the National Advisory Committee for Aeronautics, the International Meteorological Organization, the Guggenheim Committee on Aeronautical Meteorology, and other organizations including the Royal Meteorological Society, the American Meteorological Society, the Washington Philosophical Society, The Washington Academy of Sciences, the American Geophysical Union and fellow of the American Association for the Advancement of Science. His relation with some of these organizations was not a passive one for he served the American Meteorological Society as Treasurer and President, the Washington Philosophical Society as Treasurer, and the Geophysical Union as Chairman of the Section on Meteorology.

He was the author of a number of technical articles and in addition was author of *The Standard Atmosphere*, *Aerological Survey of the United States*, and *Aeronautical Meteorology*.

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